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Figure 11.4-1 Containment spray System



## **11.4 CONTAINMENT SPRAY SYSTEM**

### **Learning Objectives:**

1. State the purposes of the containment spray system.
2. List the suction supplies to the containment spray pumps and when each would be used.
3. Explain why trisodium phosphate is added to the containment sump during a loss of coolant accident.

### **11.4.1 Introduction**

The containment spray system is an engineered safety features system that maintains containment building integrity, helps to maintain containment sump pH neutrality, and cools the containment building recirculation sump water.

Containment integrity is assured by a reduction in building pressure. The reduction in containment building pressure is achieved by condensation of the steam released from the reactor coolant system during a loss-of-coolant accident or from the steam generator during a main steam line break by the spray droplets from the containment spray nozzles.

Two safety benefits are realized by pressure reduction. First, the reduction in pressure minimizes the probability of losing the containment, which is the final barrier to the release of radioactive fission products to the public. The second benefit is the reduction of the driving force for radioactive material in the containment building atmosphere if there is any leakage out of the containment.

The addition of trisodium phosphate to the containment sump following a loss-of-coolant accident maintains sump pH approximately equal to 7.0. This value aids in the minimizing of stress corrosion cracking of metals during the operation of the safety injection systems.

Finally, the shutdown cooling heat exchangers are normally aligned to the containment spray pump discharges. During the recirculation phase after a loss-of-coolant accident, the hot sump water is discharged through the heat exchangers for cooling purposes.

## 11.4.2 System Description

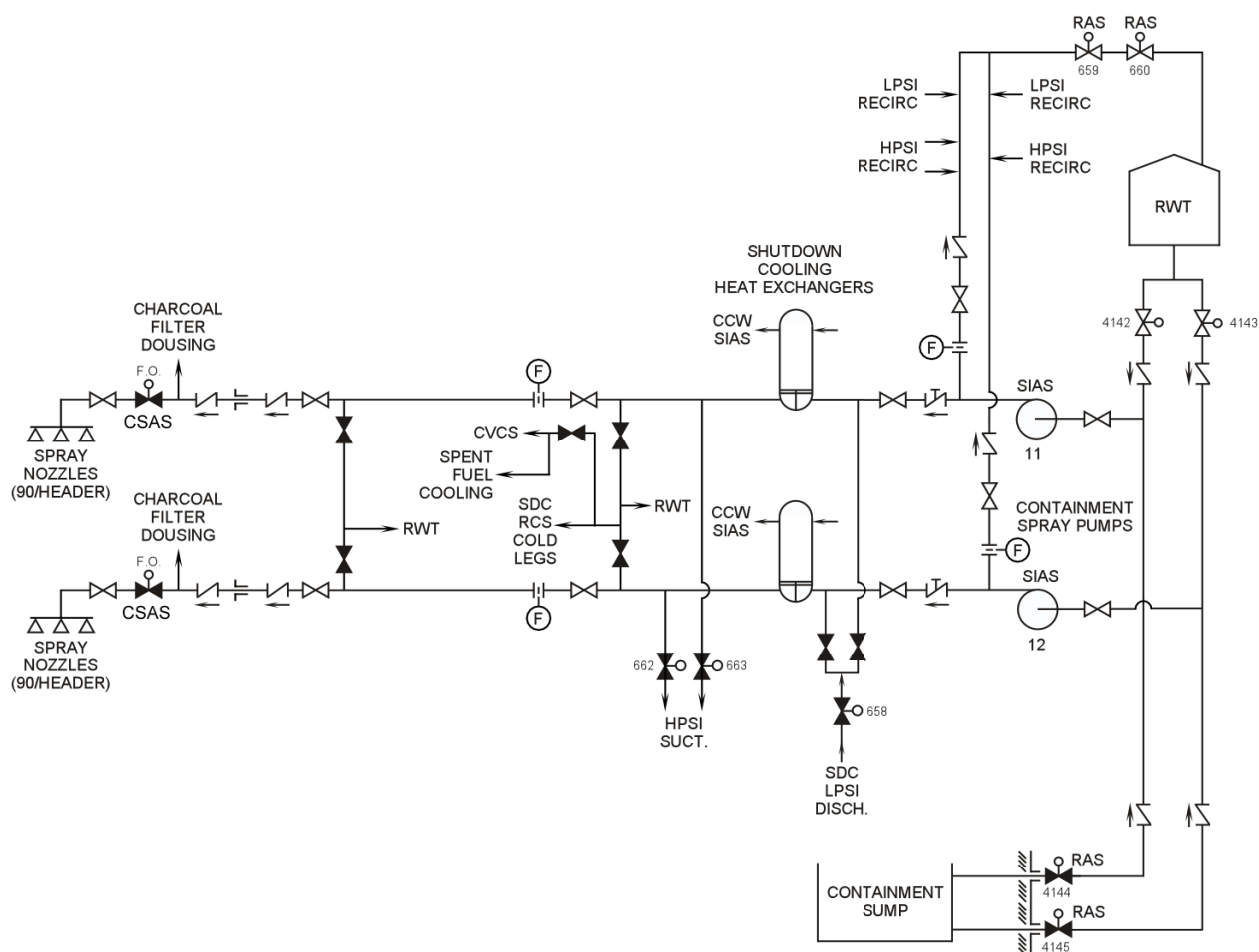


Figure 11.4-1 Containment Spray System

The containment spray system consists of two redundant trains with each train containing a spray pump, shutdown cooling heat exchanger, spray nozzles and associated valves. A containment spray actuation signal actuates the system when containment pressure exceeds the high-high setpoint of four and one-quarter (4.25) psig.

Two suction sources are available to the containment spray pumps. The first suction source is the refueling water tank, which provides borated water to the pumps during the injection phase after an accident. When the refueling water tank reaches a low level (30 in.), a recirculation actuation signal is generated. This signal automatically transfers the suction of the spray pumps from the refueling water tank to the containment sump. Regardless of the suction source, the containment spray pumps discharge to the containment spray headers via the shutdown cooling heat exchangers.

The shutdown cooling heat exchangers are installed on the discharge of the containment spray pumps to cool the hot recirculation water from the sump. The heat exchangers are cooled by the component cooling water system. The motor-operated component cooling water supply valves are automatically opened when a safety injection actuation signal is actuated. Cool water from the heat exchangers then travels to the spray headers.

The flow of spray fluid to the spray headers is controlled by isolation valves that are automatically opened by a containment spray actuation signal (CSAS) at a containment pressure of 4¼ psig on two-out-of-four containment pressure detectors. The pressure detectors are separate from the pressure detectors used to generate a safety injection actuation signal. When the valves open, spray water travels to the spray nozzles located in the containment building dome. The nozzles divide the spray fluid into small droplets which fall through the containment building atmosphere to the building sump. The containment spray system is redundant to the containment cooling system.

### **11.4.3 Component Description**

#### **11.4.3.1 Containment Spray Pumps**

The containment spray pumps, manufactured by Byron Jackson, are single-stage, horizontal, centrifugal pumps. They have mechanical seals backed up with an auxiliary gland. Each pump is driven through a coupling by a 200 hp, 4160 Vac induction motor. Containment spray pump 11 receives power from 4 kV unit bus 11, while containment spray pump 12 receives power from 4 kV unit bus 14. Both containment spray pumps start automatically when a safety injection actuation signal (SIAS) is generated.

Each pump has a capacity of 1400 gpm in the injection mode of operation, and 1630 gpm in the recirculation mode. The minimum allowable flow for a containment spray pump is 50 gpm. In the injection mode of operation, the containment spray pumps must discharge against containment pressure, while in the recirculation mode the containment spray pumps take a suction from the containment building and thus do not have to pump against containment pressure. This reduced back pressure results in the higher spray pump capacity in the recirculation mode.

The pumps are provided with minimum flow recirculation lines which permit a flow of 50 gpm from each pump to recirculate back to the refueling water tank during the injection mode of operation. The recirculation path is isolated upon the receipt of a recirculation actuation signal. The “A” pump is powered from the “A” emergency diesel bus, while the “B” pump is powered from the redundant “B” emergency diesel bus.

#### **11.4.3.2 Shutdown Cooling Heat Exchanger**

There are two shutdown cooling heat exchangers in each unit. They are used to remove core decay heat and reactor coolant sensible heat during plant cooldowns and cold shutdown conditions. The heat exchangers also cool the containment spray water during containment spray system operations.

The heat exchangers are a U-tube design with two tube side passes and one shell side pass. Component cooling water passes through the shell side, while the tube side water is from the safety injection and/or containment spray system. The tubes are stainless steel and the shell is carbon steel. The heat exchangers are located in the emergency core cooling system pump room of the same corresponding emergency core cooling system train's pump.

Each heat exchanger is protected against over pressurization on the tube side by a relief valve located on the recirculation line from the heat exchanger outlet back to the high pressure safety injection pump suction. Both relief valves have a set point of 500

psig and are sized to accommodate the pressure developed due to a sudden temperature increase of the heat exchanger contents. The worst thermal transient considered is expected to occur at the beginning of containment spray recirculation with water temperature changing from 40°F to 276°F in 10 seconds.

Each heat exchanger is sized to maintain a refueling water temperature of 130°F or less, 27½ hours after reactor shutdown, assuming the core has operated at its design power for an infinite duration. This feature also assumes the component cooling water supplied to the heat exchanger is at its maximum design temperature of 95°F. The heat removal capacity of the containment spray system is 240 million Btu per hour. The maximum system heat load, which occurs 70 seconds after the start of a LOCA, is 237 million Btu per hour.

#### **11.4.3.3 Trisodium Phosphate Baskets**

Three baskets located on the containment floor contain the dry trisodium phosphate. Containment spray water and/or safety injection water on the containment floor dissolves the trisodium phosphate and carries it through the containment spray and safety injection systems. The trisodium phosphate, in solution, changes the pH of the water from approximately five to seven. This neutralization of the water ensures iodine remains in solution and minimizes stress corrosion cracking of certain materials in the safety injection system.

The trisodium phosphate baskets are located approximately six inches above the containment floor, at approximately 120° intervals. Each basket is five feet wide by five feet long and 18 inches in height. The basket has a solid top and bottom, with stainless steel mesh screen sides. The safety injection and containment spray water dissolves the trisodium phosphate as the water rises above the containment floor. Mixing of the trisodium phosphate occurs as the solution is continuously recirculated. Technical specifications require a minimum of 287 cubic feet of trisodium phosphate be contained within the three trisodium phosphate baskets.

#### **11.4.3.4 Containment Spray Headers**

Each containment spray header contains 90 nozzles, each of which is capable of a design flow of 15.2 gpm. The nozzles produce a mass equivalent drop size of approximately 700 microns at rated system conditions.

The spray headers are installed in the top of the containment building dome in concentric circles. Each of the circles is supplied from a separate containment spray train in an alternating fashion allowing complete coverage of the building in the event of a single containment spray pump failure.

The spray header isolation valves are normally shut, and open automatically on a containment spray actuation signal (CSAS) generated by the engineered safety features actuation system. The spray header isolation valves open on a containment spray actuation signal, while the Containment Spray Pumps are started on Safety Injection Actuation Signal to prevent inadvertent spraying of the containment. The spray header isolation valves fail open on loss of power or air. While the isolation valves are open, containment isolation is maintained by check valves in the spray header on either side of the containment building.

Each containment spray header has a connecting line which directs spray water to the containment iodine removal filter units. The spray water is used to douse the charcoal filter beds in the filter units, in the event decay heat causes the charcoal filter temperature to rise above 300°F. A solenoid operated isolation valve in the connecting line to the spray header is used to send spray water to the iodine removal filter units. These isolation valves are controlled by hand switches from the control room. Once the charcoal filter high temperature condition has cleared, the filter dousing is stopped.

#### **11.4.4 Containment Spray System Design Basis**

The containment spray system is designed to provide sufficient heat removal capability to maintain the containment pressure and temperature below their design values in the event of a loss-of-coolant accident or main steam line break accident.

The containment spray system is redundant with the containment air cooling system. Any of the following combinations of the two system's equipment provides sufficient heat removal capability to maintain the post-accident containment pressure and temperature below their design values:

- Two containment spray pumps provide 100% cooling capacity, or
- One containment spray pump and two (out of four) containment air cooling units provide greater than 100% cooling capacity, or
- Three (out of four) containment air cooling units provide 100% cooling capacity.

The heat removal capacity of the containment spray system is sufficient to overcome the design maximum heat load occurring in the containment building 70 seconds after the start of a loss-of-coolant accident.

#### **11.4.5 System Operations**

Normally, the containment spray system is in a standby mode of operation with none of its equipment in service. Two different conditions can change the status of the spray system. The first condition is an accident that requires the operation of the containment spray system. The second occurrence is a cooldown of the reactor coolant system which involves the use of the shutdown cooling heat exchangers.

##### **11.4.5.1 Injection Mode**

Following an accident which results in a safety injection actuation signal, the two containment spray pumps automatically start. If containment pressure subsequently rises to the containment spray actuation signal setpoint, the containment spray header isolation valves open. This mode of system operation is called the injection mode. Each containment spray pump takes a suction on independent outlet lines from the refueling water tank. Each containment spray pump discharges borated water to one shutdown cooling heat exchanger where it is cooled by component cooling water. Each shutdown cooling heat exchanger sends the cooled water to a separate containment spray header, whose isolation valves open on a containment spray actuation signal.

Each spray header terminates in a separate circular ring which sprays the borated water into the containment atmosphere. The cool spray drops absorb heat from the

containment atmosphere, and thus reduce the containment pressure and temperature. The spray water falls to the containment floor where it collects in the containment sump.

#### **11.4.5.2 Recirculation Mode**

When the refueling water tank level reaches a low level setpoint of 30 inches, the engineered safety features actuation system generates a recirculation actuation signal, which initiates the recirculation mode of containment spray operation. Upon receipt of a recirculation actuation signal, the two containment sump isolation valves open, and containment sump water is recirculated by the containment spray pumps through the shutdown cooling heat exchanger and back into containment as spray. Once initiated, recirculation continues until terminated or modified by operator action.

#### **11.4.5.3 Shutdown Cooling Mode**

During shutdown cooling operations, the discharge of the low pressure safety injection pumps is routed to the shutdown cooling heat exchangers. In order to prevent inadvertent containment building spray downs with radioactive reactor coolant system water the following changes are made to the spray system:

1. The spray headers are isolated and
2. The containment spray pump stopcheck valves are closed and the pump breakers are racked down.

The containment spray and low pressure safety injection systems are returned to their normal alignment during the plant heatup.

#### **11.4.6 PRA Insights**

The containment spray system is used to remove heat from the containment following a high energy fluid break (steam, feed, or primary) into the containment. Many PRA studies consider the failure of the containment and subsequent release of fission products to the public. If the CS system fails, then the pressure reduction and scavenging functions are lost. If the fan coolers are also inoperable, containment pressure can exceed design pressure, and containment failure can occur.

Probable causes of a loss of containment spray systems include failure of the motor operated suction valves, closed manual valves in the suction lines, loss of ac power supplies, failure of the containment spray pumps to start, and failure of the containment spray pumps to run after starting. It should be noted that the suction lines to the containment spray pumps are also utilized by the high pressure safety injection and low pressure safety injection systems. Therefore, a loss of suction to the spray pumps could also affect the emergency core cooling system pumps.

NUREG-1150 studies on importance measures have shown that the containment spray system is not a contributor to either risk achievement or risk reduction.

#### **11.4.7 Summary**

The containment spray system maintains the containment fission product barrier by reducing containment pressure following a loss-of-coolant accident or steam line break. In addition, the system cools the containment sump water during the recirculation phase of a loss-of-coolant accident. Trisodium phosphate is added to the containment sump



to maintain sump pH within assumptions used to prevent stress corrosion cracking. The system is actuated by two-out-of-four high-high containment building pressure signals (4¼ psig).



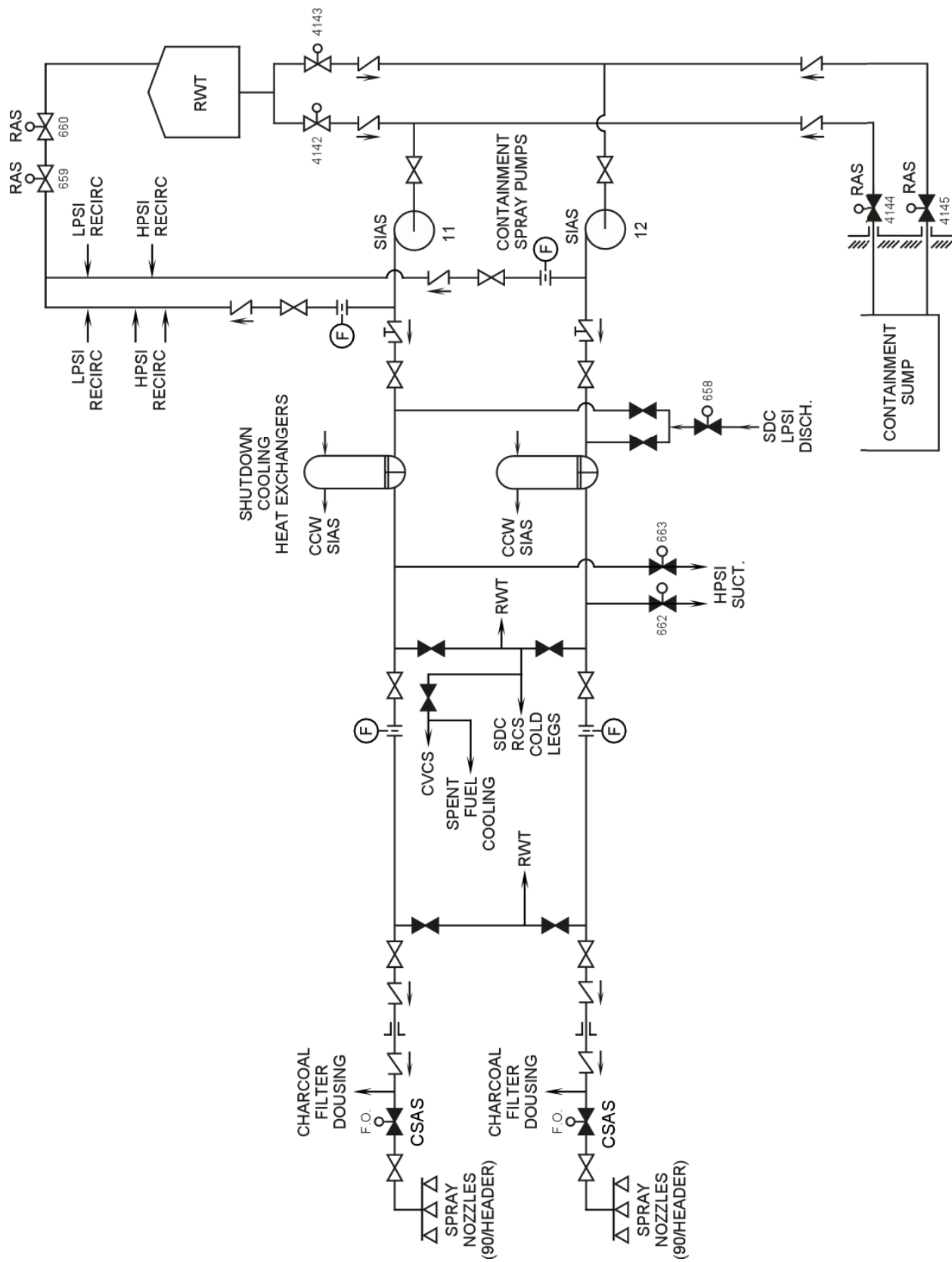


Figure 11.4-1 Containment spray System